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Full Paper

POTENTIAL OF DIKA NUT OIL AS LUBRICANT FOR SUSTAINABLE TECHNOLOGICAL GROWTH

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ABSTRACT

The paper presents a report on the physico-chemical properties and lubricity grade of refined Dika nut oil for use as lubricant, in consonance with sustainable technological development for vision 20:2020. Chemical properties such as iodine, acid and saponification values of the oil were evaluated. The physical properties of the oil were characterized in terms of its density, viscosity at 40 and 100°C, flash and pour points. The lubricity of the oil was estimated on the basis of its viscosity, comparing with Society for Automotive Engineering (SAE) oil grades. Test results showed that the oil has the following physical properties: viscosity of 57.57 cSt at 40°C and 6.78 cSt at 100°C; viscosity index of 71; flash point of 296°C; cloud point of 37°C; pour point of 32°C; and specific gravity of 0.928 at 15°C. The chemical properties in terms of its oxidative stability, saponification, acid and iodine values were 250 hours, 199.72 mgKOH/g, 0.3 mgKOH/g and 0.518%, respectively. The viscosity of the oil at 40 and 100°C ranked between SAE 20 and 30 lubricating oil at both temperatures. The oil, thus, shows a strong potential for use as lubricant.

Keywords: Biodegradable, lubricant, Dika nut, lubricity, oiliness

1. INTRODUCTION

The key goal of vision 20:2020 is to make Nigeria one of the 20 largest economies in the world, to consolidate her leadership role in Africa and establish her as a significant player in the global economic and political arena (Nigeria Vision 2020, 2009). This expectation suggests a definite need for increase in technological growth in the exploitation of the vast natural resources of the country. This will ultimately lead to a diversification of the economy, to relieve the country's over reliance on crude oil. The projection (Iseghohi, 2008) of a Gross Domestic Product of between $500 and $800 could then be feasible.

The expected technological growth implies that more machines and vehicles will be put to use and, there will be increasing demands for lubricants in the maintenance of the machines. It is also well known that without the improvement in lubricant technology, the advancement achieved in other branches of engineering such as design and manufacturing of machineries would have been impossible (Dara, 2007). Currently, nearly all lubricants in use in the country are petroleum based, with the attendant risk of environmental degradation when disposed because mineral oils are non-biodegradable. Researchers (Oseni et al., 2006; Marth, 2007; Petlyuk and Adams, 2004) have therefore focused on the development of straight and blended vegetable oil-based lubricants, which are non-toxic and are biodegradable. This is strictly important, because about 60% of spent lubricants end up in the soil and water, constituting environmental hazard if non-biodegradable.

A data bank of classification of available vegetable oil lubricants is therefore essential, to provide viable alternatives to the mineral oils, in the anticipated technological growth. Vegetable oils are renewable and are also preferred in certain applications where mineral oil contamination is inadmissible (Honary, 2004). Increased use of the oil-seeds will also stimulate new challenges in crop production and bioengineering, to contribute further to attaining the vision 20:2020.

In this regard, many oil seeds such as, linseed with 35 to 44% oil content (Willem et al., 2008; Ibrahim and Onwualu, 2005); groundnut, 38 to 50% (Ibrahim and Onwualu, 2005; Adeeko and Ajibola, 1990) and palm kernel, 46 to 57% (Akinoso et al., 2006; Faborode and Favier, 1996) have been exploited. However, the Dika kernel which contains about 60% oil, large quantity of saturated fatty acid, small quantity of unsaturated fatty acid and similar chemical constituents when compared with palm kernel, remains unexploited for its lubricity (Leakey and Tchoundjeu, 2001; Ogunsina et al., 2008; Atangana et al., 2002). In addition, the Dika tree has been identified as the most important tree for domestication in West and Central Africa, because of its termite resistant wood (Leakey et al., 2004). A corresponding effort in the increased exploitation of the crop is therefore worthwhile as it would add to the needed impetus for its cultivation.

Consequently, the goal in this work was to determine the suitability of Dika nut oil as lubricant. However, impurities are not desirable in lubricants, so that, the refined Dika nut oil was used. Also, because the lubricity of oil depends on its physico-chemical properties, the main objectives of this work, therefore, were to:

(a) determine the physical properties such as viscosity, pour and flash points, and density of refined Dika nut oil;
(b) evaluate chemical properties of the oil; and
(c) obtain the lubricity grade of the oil.

2. MATERIALS AND METHODS

2.1. Materials Preparation

Based on a preliminary experiment (Abidakun, 2009) coarsely ground Dika kernel (particle size of between 1.4 and 2.8 mm) at 6% moisture content (w.b.) was preheated at 100oC for 10 minutes and pressed in a hydraulic press to extract the oil. The oil was then refined by adding 3% by volume of water to the expressed oil. The mixture was agitated mechanically for 60 minutes at 70ºC, to hydrate the phospholipids and gums. The oil was filtered and 1% concentrated alkali solution (Sodium hydroxide) was added to neutralize the free fatty acids. The alkali solution was added to the oil, heated to 40oC in an oven and was properly mixed for 35 minutes. The temperature was then increased rapidly to 60oC, to break the emulsion. Temperature was monitored by using a thermocouple with digital readout. After breaking the emulsion, the heat was turned off and the solution was allowed to settle for 4 hours before it was filtered. Distilled water, 10% by volume preheated to 50oC was added to the neutralized oil and then heated to 95oC for 4 hours in order to evaporate the water. This was followed by drying with Silica gel to obtain the refined oil.

2.2. Determination of Chemical Characteristics

2.2.1 Neutralisation value

A measure of 5 g of refined Dika nut oil was weighed into a dried 250 mL flask, using a digital electronic balance, Mettler PL 1200, with precision of 0.001 g. A quantity of 50 mL of solution made up of equal volume of 95% ethanol and diethyl ether was added and then gently mixed to dissolve the oil. The mixture was heated at 40°C to bring mixture to complete solution. The mixture was then titrated with 0.1 N Methanoic potassium hydroxide (KOH), using 1 mL of phenolphthalein indicator, until a slight pink colour persisted for 15 seconds. The acid value was computed (Fasina, 1988) using Equation 1.

$$\text{Acid value} = \frac{V \times F \times 56.1}{m} \quad \ldots \quad (1)$$

where, V is sample titre value in mL; F is Normality for Me-KOH and m is the sample mass in g.

2.2.2 Saponification value

A measure of 2 g of Dika nut oil was weighed into a conical flask, and 25 mL of 0.5 alcoholic KOH was added to the oil in the flask. A long air condenser was attached and the flask was heated until the solution became homogenous (saponification was completed). The boiling, accompanied by agitating the content occasionally, was done for 30 minutes at such rate as to prevent loss of alcohol from the air condenser. The solution was allowed to cool and 1 mL of phenolphthalein indicator was added; while the excess alkali was titrated with 0.5 N HCl. A blank determination at the same time and under the same conditions using the same quantity of KOH solution was carried out. The saponification value was obtained (Fasina, 1988) as follows

$$\text{Saponification Value} = \frac{56.1 \times N \times (V - U)}{W} \quad \ldots \quad (2)$$

where, V is the blank level in mL; U is the titration volume for sample in mL; W is the mass of sample in g; N is the normality HCl solution; and 56.1 is the concentration conversion coefficient for the potassium hydroxide used. The 56.1 is the equivalent mass of potassium hydroxide.

2.2.3 Iodine value

A quantity of 0.25 g of dika nut oil was weighed into a 300 mL glass stoppered bottle and 10 ml chloroform was added to dissolve the oil. Hanus iodine solution of 30 mL was then added from a pipette and was stirred by swirling the content of the stoppered flask. The bottle was allowed to stand for 30 minutes to complete the halogenation. Thereafter, 20 mL of 15% potassium iodide and 100 mL of distilled water were added to separate the chloroform from the solution. The solution was then titrated with Sodium thiosulphate solution using 2 mL of starch indicator solution. A blank containing all the components except Dika nut oil was carried out following the same procedure as stated above and the iodine value was determined (Fasina, 1988) using Equation 3.

$$\text{Iodine value} = \frac{(T_b - T_s) \times N \times 12.69}{W} \quad \ldots \quad (3)$$

where, T_b is mL of thiosulphate solution for blank titration; T_s is mL of thiosulphate solution for sample; N is normality of sodium thiosulphate; W mass of sample in g; and 12.69 is the equivalent mass of iodine.

2.3. Determination of Physical Properties

2.3.1 Viscosity

The refined oil was sucked into one arm of a viscometer using its auxiliary pump. The viscometer was then placed inside the thermostatic oil bath which had been pre-heated to the required temperature. The viscometer containing the oil was placed inside the bath for 30 minutes, to adjust the temperature of the oil to that at which the viscosity was to be taken. The oil was sucked into the second arm of the viscometer and the time taken in seconds for the oil to flow through an orifice at this temperature was noted. The kinematic viscosity of the oil was derived following the procedure by the viscometer manufacturer. The viscosity of the oil was taken at 40 and 100°C.

2.3.2 Cloud and pour points

The cloud and pour point were determined by placing a quantity of the heated oil inside a test tube, and introducing it into a cold bath. The test tube was swirled gently but steadily in the bath to facilitate even dissipation of heat. The cooling continued until the oil became solidified. The temperature of the oil at which the first cloudy oil was noticed was taken as the cloud point; while, the temperature at which there was no movement of oil when the test tube was bent horizontally was taken as the pour point.

2.3.3 Flash point

The Penken Martens close cup flash point tester was used for determining the oil's flash point. The cup was filled to a specified point with the refine oil and placed inside the holder so as to heat it over a flame. As the heating continued, the flame placed at a distance from the oil's surface travels across the surface of the oil. This continued until a spark was notice on the surface of the oil. The temperature at which the spark occurred was taken as the flash point.

2.3.4 Oxidative stability

The oxidative stability of the oil was determined following the ASTM D943 method (Petlyuk and Adams, 2004). One percent by volume of water was added to 200 mL of oil placed inside a container with metallic copper as catalyst to the oxidation reaction. This combination was heated at 150°C in the open air so as to provide the oxygen required for the oxidation. The neutralization number of the heated oil was tested at intervals of fifty hours in order to determine the time at which the oil's neutralization number was up to 2 mgKOH/g of the oil.

2.3.5 Specific gravity

The oil was heated and poured into a 1000 mL measuring cylinder to permit the determination of the specific gravity. Graduated glass hydrometers were dropped inside in turns until the one where the reading could be made was achieved. The value of the specific gravity was then read off the graduated stem of the glass hydrometer. The specific gravity was determined at 36°C and was converted to specific gravity at 15°C by using the relationship (Godfrey and Herguth, 1996) in Equation 4.

$$S.G_{@15/15} = [(T - 15^oC) \times 0.00061] + Y \quad ... \qquad (4)$$

where, T is the temperature at which the specific gravity was determined using the hydrometer and Y is the observed specific gravity at temperature T.

2.4. Assessment of Lubricity Grade

In order to determine the lubricity grade, the refined oil was charted against the SAE viscosity chart (Hamrock et al., 1998) using the value of the kinematic viscosity obtained at 40 and 100°C. The chart was then used to obtain the range within which the oil was ranked on SAE scale. The refined Dika nut oil was also compared with commercial grade lubricants: biodegradable hydraulic oil SAE 10W (ISO VG 46); engine oil, SAE 10W-40; and way lubricant ISO 68.

3. RESULTS AND DISCUSSION

A summary of the physico-chemical properties of oil is shown in Table 1. The oil exhibited an iodine value of 0.518% which indicates a tendency of high viscosity. High iodine value is undesirable because it lowers the viscosity of oil, and increases the oil's rate of oxygen absorption from the air at ordinary temperature. Oxygen absorption causes polymerization of the acid and renders the oil unfit for lubrication due to rapid sludge formation (Akbar et al., 2009).

A high saponification value of 199.72 mgKOH/g shows that the oil has high molecular weight fatty acids, which is an indication of high antifriction property. The importance of high saponification value is further reiterated by the addition of fatty additives to certain lubricants such as worm gear oils, steam cylinder oils, machine tool way lubricants, and pneumatic tool oils so as to improve their antifriction properties (Akbar et al., 2009). Also, the refined oil has an acid value of 0.3 mgKOH/g, which is relatively low enough to make it suitable for use as a lubricant. An ideal lubricant should be free from acids which cause corrosion of the metals in the system and results in the oil's poor oxidative stability (Bongardt, 1995).

The kinematic viscosity of the oil is 57.57 cSt at a temperature of 40°C, 6.78 cSt at 100°C, yielding a viscosity index of 71. On the basis of the viscosity, refined Dika nut oil lies between SAE 20 and 30 lubricating oil at 40°C and 100°C (Fig. 1). The viscosity index which shows how much the viscosity of the oil changes with temperature, falls within the range of 55 and 100, where the viscosity index of most industrial mineral lubricating oils lie (Godfrey and. Herguth, 1996). The low viscosity index shows that the oil's viscosity will change rapidly with temperature. However, the viscosity index can be enhanced by adding some viscosity index improver.

The observed flash point of 296°C for refined Dika nut oil is higher than 165°C and 146°C required for turbine and insulating oil, respectively (Demirbas, 2008). This shows that the oil can be used as lubricant without fear of fire hazard. The value of flash point obtained compares favourably well with flash point of other vegetable oils: 247°C for linseed, 228°C for palm oil, 255°C for soybean oil and 270°C for peanut oil (Demirbas, 2008). The value obtained was also higher than that of other commercial lubricants (Table 2). A high flash point is desirable for lubricants because it provides good resistance to combustion and a low degree of evaporation at normal temperatures. For a lubricant, flash point in the range of 149°C to 265°C are required for the lightest and heaviest oils, respectively.

Pour point which is the lowest temperature at which the oil becomes solid is relatively high for this oil when compared with other commercial grade lubricants (Table 2). A low value of pour point is required for a lubricant to function well at low temperature. Cloud and pour point of 37 and 32°C, respectively, were observed for the refined Dika nut oil. These values are too high and, show that the oil has poor low temperature property. The low temperature property can be improved by introducing appropriate pour point depressant additives (Godfrey and Herguth, 1996).

The refined oil has a specific gravity of 0.928 at 15°C and this falls within the range 0.86 to 0.98 exhibited by mineral oils (Godfrey and Herguth, 1996). The value of specific gravity obtained for this oil shows that the oil is lighter than water and will float when spilled in water. It is therefore not suitable for use in underwater military operations (Marth, 2007).

For the refined Dika nut oil to serve its intended function as a lubricant, a high oxidative stability is required. Refined Dika nut oil has an oxidative stability of 250 hours which is relatively high compared to the values for other vegetable oils such as, soybean and linseed (Honary, 2004). Vegetable oils generally have poor oxidative stability, but could be improved by adding oxidation inhibitor additives to suppress the oxidation reaction, so as to prevent the formation of more acid.

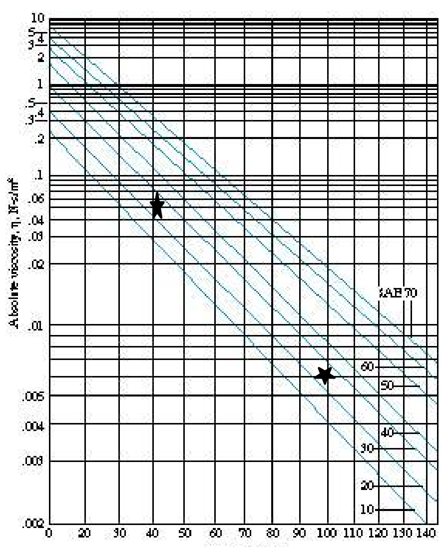

Figure 1: *SAE lubricating oil chart showing the position of refined Dika nut oil at 40 and 100°C; ★, Dika nut oil; SAE chart from Hamrock et al. (1998).*

4. CONCLUSION

The physical and chemical properties of refined Dika nut oil were evaluated to verify the suitability of the oil for use as lubricant. In view of the biodegradability of vegetable oils, the Dika nut oil with acid value of 0.3 mgKOH/g; iodine value of 0.518%; saponification value of 199.72mgKOH/g; flash point of 296°C and specific gravity of 0.928 showed a strong potential for use as environmentally friendly lubricant. The oil, however, requires the addition of appropriate viscosity index improver and pour point depressant to make it suitable for use at temperature below 32°C. On the basis of its viscosity, the oil was ranked between SAE 20 and 30 lubricating oil at 40°C and 100°C. Conclusively, Dika nut oil provides a source of future lubricant and economic benefits while reducing environmental impact.

Table 1: Properties of Dika nut oil

S/N	Properties	Values
1	Acid Value (mgKOH/g)	0.3
2	Saponification value (mgKOH/g)	199.72
3	Iodine value (%)	0.518
4	Kinematic Viscosity at 40 °C (cSt)	57.57
5	Kinematic Viscosity at 100 °C (cSt)	6.78
6	Viscosity Index	71
7	Flash point (°C)	296
8	Cloud point (°C)	37
9	Pour point (°C)	32
10	Specific gravity at 15 °C	0.928
11	Oxidative stability (hours)	250

Table 2: Properties of Dika nut oil and other types of lubricant

Properties	Oil Type			
	A	B	C	D
Kinematic Viscosity at 40°C	48.7	108.5	68.4	57.57
Kinematic Viscosity at 100°C	8.7	15.4	8.8	6.75
Viscosity Index	160	149	101	71
Flash point	220	220	236	296
Cloud point	-	-	-	37
Pour point	- 58	- 33	- 12	32
Specific gravity at 15°C	0.921	0.872	0.885	0.928

A is Biodegradable hydraulic oil SAE 10W (ISO VG 46); B is Engine oil SAE 10W-40; C is Way lubricant ISO 68; and D is the refined Dika nut oil. Properties of the commercial lubricants were taken from Abidakun (2009)

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